American Journal of Industrial Medicine 13:59–69 (1988)

Smoking and Degree of Occupational Exposure: Are Internal Analyses in Cohort Studies Likely to Be Confounded by Smoking Status?

J. Siemiatycki, PhD, S. Wacholder, PhD, R. Dewar, MSc, L. Wald, BSc, D. Bégin, BSc, L. Richardson, MSc, K. Rosenman, MD, and M. Gérin, PhD

Occupational cohort studies are usually carried out without the benefit of information on smoking habits of cohort members. One common approach to avoid confounding bias related to smoking habits is to carry out an internal analysis, comparing workers with different degrees of occupational exposure. The premise behind this approach is that within a cohort there is unlikely to be correlation between degree of exposure and smoking habits. If this were untrue, smoking could confound the disease-exposure relationships. Our purpose was to verify the premise. The study sample consisted of 857 French-Canadian men born between 1910 and 1930, with 11 or fewer years of education, and interviewed around 1980 in the context of an occupational cancer case-control study. For each man we had information on smoking habits, job history, and a history of the chemicals he was exposed to in each of his jobs. We computed two indices of the dirtiness of workers' job histories: one based on the job titles held by the man and a second based on the degree of exposures to workplace substances. There was no correlation between these indices of job dirtiness and smoking history. We also examined the smoking-exposure relationship among the subsets of men who had been occupationally exposed to ten especially noticeable substances. Within the subsets, there was no indication of a consistent difference among the smoking subgroups in level or duration of exposure to these index substances. These findings do not support the view that nonsmokers sought out cleaner job environments than smokers; they imply that internal analyses of "dose-response" in cohort studies are unlikely to be seriously confounded by smoking habits.

Key words: cigarette, confounding bias, dusts, epidemiologic methods, fumes, study design

INTRODUCTION

The most commonly used research design in occupational cancer epidemiology has been the historic cohort study. As a general rule, such studies suffer from the

Epidemiology and Preventive Medicine Research Centre, Institut Armand-Frappier, Laval-des-Rapides, Quebec, Canada (J.S., R.D., L.W., D.B., L.R.).
Department of Epidemiology and Biostatistics, McGill University, Montreal (J.S., S.W.).
Robert Wood Johnson Medical School, Piscataway, NJ (K.R.).
Département de Médecine du Travail et d'Hygiène du Milieu, Université de Montréal, Montréal (M.G.).
The current address for S. Wacholder is The National Cancer Institute, Bethesda, MD 20892.
Address reprint requests to Jack Siemiatycki, Epidemiology and Preventive Medicine Research Centre, Institut Armand-Frappier, 531 des Prairies Blvd., Laval-des-Rapides, Quebec, Canada H7V 1B7.
Accepted for publication July 28, 1987.

difficulty or impossibility of obtaining information on important confounders, primarily smoking history. In the US, and presumably elsewhere, there are quite different smoking patterns by occupation [Sterling and Weinkam, 1978; Brackbill et al, 1988; Stellman et al, 1988]. The impact of this variation on estimates of risk which are not adjusted for smoking remains controversial [Steenland et al, 1984; Asp, 1984; Blair et al, 1985].

One of the approaches to analysing studies of cohorts of exposed workers is to carry out an internal analysis, comparing workers with different degrees of occupational exposure. A premise behind this approach is the following: even if workers in this cohort have a different smoking profile from the general population, there is no correlation within the cohort between smoking habits and degree of occupational exposure among the exposed workers and thus internal comparisons are not confounded by smoking. Although the premise is plausible, its truth is not self-evident. Alternative hypotheses can be formulated to the effect that workers who smoke are by nature "risk takers" or that they are less sensitive than nonsmokers to the irritating effects of dusts, fumes, and smoke in their occupational environment. Nonsmokers may quit a dirty occupation sooner than smokers, which would lead to a correlation between smoking habits and duration of exposure. Even within a job category, nonsmokers may select themselves into relatively cleaner job environments, which would lead to a correlation between smoking habits and cumulative levels of exposure. Under these alternative assumptions, internal comparisons of exposure categories in a cohort of workers in a dirty environment could be biased.

In this paper we will examine the relationship between smoking habits and degree of exposure to workplace substances. The data were collected as part of a large case-control study of occupational factors in cancer. For each subject, detailed information was obtained on the job history, on the exposure to chemical and physical agents in each job, and on a variety of social factors including smoking.

METHODS

Since 1979 we have been conducting a cancer case-control study designed to assess associations between several sites of cancer on the one hand and scores of occupational exposures on the other. Details of the study design and methods can be found elsewhere [Siemiatycki et al, 1981, 1986; Gérin et al, 1985].

Eligibility criteria for cases included the following: male, aged 35–70, resident in the Metropolitan Montreal area, with a newly diagnosed tumor of any of the 19 sites of cancer selected for study. All major hospitals in the area have participated, thus providing a population-based series. In addition, a general population control series was selected from electoral lists. Each eligible subject was approached for an interview and nearly 3,000 subjects were interviewed in the period 1979–1983.

The questionnaire was in two parts: (a) a structured section requesting information on important potential confounders, including smoking habits, and (b) a semistructured probing section designed to obtain a detailed description of each job the subject has had in his working lifetime. The interviewers were trained to probe for as much information as the patients could supply on: the company's activities, the raw materials, final product, machines used, the man's responsibilities for machine maintenance, the type of room or building in which he worked, activities of workmates around him, presence of gases, fumes or dusts, and any other information

which could furnish a clue as to possible chemical or physical exposures incurred by the subject. A team of chemists and hygienists working with us had the responsibility of examining each completed questionnaire and translating each job into a list of potential exposures. They did this on a checklist form which explicitly lists some 275 of the most common occupational exposures. The team of chemists relied on the following sources as a basis for this retrospective exposure assessment: their own industrial experience and chemical knowledge, old and new technical and bibliographic material describing industrial processes, and consultations with experts familiar with particular industries. For each product thought to be present in each job, the chemists provided the following information:

(a) Concentration of the agent in the environment (low, medium, high). The concentration attribution was on a relative rather than absolute scale.

(b) Frequency of exposure during a normal workweek (less than 5%, 5–30%, 30+ %).

(c) Their confidence that the exposure actually occurred (possible, probable, definite).

(d) Degree of "noticeability" of the substance to the worker (low, medium, high). This index does not concern toxicity of the substance; rather, it conveys the potential for being bothersome or irritating to the worker (eg, hydrogen sulphide is high in "noticeability," while asbestos is low).

(e) The dates of beginning and ending of each job were recorded, and thus length of the corresponding exposures in each job.

Our objective was to examine the relationship between smoking and exposure, and to do so in circumstances which resemble those of most cohort studies. The typical cohort study population is relatively homogeneous in social, ethnic, and cohort of birth characteristics. These are factors which could easily confound the relationship between smoking and degree of exposure. Therefore we restricted attention to a subgroup of our study population which was relatively homogeneous in social and demographic terms and which would have had opportunity to go into "dirty" occupations. That is, this study was carried out among interviewed subjects (cancer cases and population controls) who were born between 1910 and 1930, were of French-Canadian origin, and had 11 years of schooling or less. A total of 857 men satisfied the inclusion criteria. These men had the following characteristics: population controls, 117; gastrointestinal cancer, 341; genitourinary cancers, 327; other cancers, 72.

The smoking information available includes age at which smoking began, age at which it ended (for ex-smokers), and average amount smoked per day during the smoking period. We have no information on changes in quantity smoked over time or on nonsmoking gaps. For the present purpose the smoking history was collapsed to a four-category variable as follows: nonsmoker, quitter, current smoker of up to 20 cigarettes per day, and current smoker of more than 20 cigarettes per day. These are categories commonly used in epidemiologic studies and have been shown to carry very distinct risks of lung cancer. A quitter was defined as a regular smoker who quit before age 50. The choice of this definition of "quitter" was related to the fact that study subjects ranged in age from 50 to 70 at the time of interview. We wanted all of the subjects to have had an equal opportunity to have become a "quitter." A second reason for using such an age cutpoint was that we wanted to increase the likelihood

TABLE I. Distribution of Subjects by Lifetime Smoking Profile*

Smoking profile	n	%
Nonsmoker[a]	100	11.7
Quitter[b]	108	12.6
Light smoker[c]	180	21.0
Heavy smoker[d]	469	54.7
Total	857	100.0

*Cancer cases and controls interviewed in 1979–1983 and satisfying the following criteria: male, born 1911–1930, 11 or fewer years of schooling, French-Canadian ethnic group.
[a]Never smoked regularly.
[b]Regular smoker (of any amount) who quit before age 50.
[c]Smoked an average of 20 or less cigarettes per day and did not quit before age 50.
[d]Smoked an average of more than 20 cigarettes per day and did not quit before age 50.

that the man quit for "aesthetic" rather than medical reasons. Table I shows the number of men in each smoking category; these are the groups among which exposure histories will be compared. Over half of this sample consisted of "heavy" smokers.

The relationship between smoking and exposure was examined in three ways, with varying indices of exposure and among various subgroups of the study sample.

Job-Title-Based Index

The first index was derived based on subjects' job titles which were coded according to the Canadian Dictionary of Occupational Titles. The chemists devised a scoring system for all four-digit codes of the classification based on their overall impression of the "dirtiness" of the typical job environment. A seven-point scale was used. Note that this was not done with reference to the idiosyncrasies of any particular person's workplace; rather, it represented an abstract entity based on a mental averaging over time and across industries and companies. By using this correspondence system the following job-title-based index was computed:

$$J = \sum_i X_i / D$$

where X_i was the score corresponding to the job held in the man's i^{th} year. The i is summed over the years of interest in the man's career. D is the total number of years of employment in the age period of interest. Division by this term has the effect of adjusting for varying unemployment gaps in different work histories. This index can be thought of as an average measure of the degree of "blue-collaredness" of the man's job-title history, without trying to account for the idiosyncrasies of his particular situation.

Exposure-Based Index

A second index was based on the job exposures attributed by our team of chemists to each man's job history:

$$E = \sum_{i} \sum_{j=1}^{275} \text{concentration}_{ij} \times \text{frequency}_{ij} \times \text{confidence}_{ij} \times \text{noticeability}_{ij} / D$$

where the four dimensions have been defined above and refer to substance j at age i. D is the total number of years of employment, and the summation was over the years of his working career. Each of the four dimensions is on a three-point scale. As a reflection of our view about the relative weights of the categories, we attributed a score of 1 to the low category, 4 to the medium category, and 9 to the high category. Thus, in a given year for a given substance, the contribution to E can vary from 0, if unexposed, to $9 \times 9 \times 9 \times 9$ if definitely exposed at highest concentration and frequency to a very noticeable substance.

Substance-Specific Analyses

Both of the above analyses were carried out among all 857 subjects and thus crossed occupational and industrial boundaries. Another set of analyses was based on the subsets of men who were exposed to each of ten selected noticeable and relatively common exposures (sulphur dioxide; welding fumes; engine emissions; gasoline; lubricating oil; solvents; paints, varnishes, stains; adhesives; excavation dust; and wood dust). For each substance studied in this way, the analysis was restricted to that subset of men who were considered definitely exposed. For each of these subsets, we computed two substance-specific indices. That is, for each substance we computed (a) the duration of exposure to the substance and (b) the level of exposure to the substance defined as concentration × frequency. It was unnecessary to introduce the confidence or noticeability factors into these substance-specific indices since this analysis was restricted to men considered definitely exposed and to substances considered very noticeable.

The subgroups analysed can be considered as cohorts of workers exposed to these selected substances. While it is most common to define cohorts on the basis of job or industry title, it is possible to define them on the basis of exposure to some substance of interest. Although we would have liked to implement analyses based on subgroups defined by job title or industry title, there were not enough subjects in such subgroups to provide adequate statistical power. There were many more subjects in subgroups defined by exposure to specific substances than by job or industry title.

The age at which employment occurred could be an important determinant of the types of exposures incurred. To eliminate the possibility of biases due to such factors, we established a fixed age window, 21–50 inclusive, and studied exposure only in this window. Furthermore, because we were interested in the dynamic relationship between smoking habits and exposure profiles, the E and J indices were computed separately for jobs held up to age 30 and for jobs held after age 30—that is, for the age windows 21–30 and 31–50. The first may be thought of as the early career in which a man's preferences are sorted out and the second as the part of his career in which he could have left a situation he considered unpleasant.

RESULTS

As was expected from the selection criteria used, this sample of men had a predominantly blue-collar profile. At age 25, 251 had white-collar occupation titles,

540 had blue-collar occupation titles, and 66 were unemployed. At age 50, the corresponding figures were 305, 521, and 31, respectively.

Lifetime nonsmokers were somewhat more occupationally stable than smokers. Nonsmokers had an average of 2.7 (±0.1) different jobs and 29.4 (±0.1) years of employment over the 30-year window, whereas smokers (all categories combined) had an average of 3.0 (± 0.1) jobs and 28.6 (± 0.1) years of employment over the same window. There were no differences among the three categories of smokers on number of jobs and years of employment.

Table II shows the mean levels of exposure, as assessed by the job-title-based index, during the early years of the man's career and during later years, for each of four smoking categories. The absolute values of the indices have no meaning. To facilitate the examination of tables, we have scaled these indices up or down so that the mean value of each index among nonsmokers is 100. Smokers and nonsmokers had similar proclivities to spend time in dirty or clean occupations in early career and similar proclivities to spend time in dirty or clean occupations in late career.

The exposure-based index takes into account the particularities of each man's job situation and thus allows for the possibility that even within occupation classes, smokers and nonsmokers may differ in degree of exposure. As shown in Table III, the exposure-based index of "dirtiness" was slightly higher among nonsmokers than among smokers in the age window 31–50. There were strikingly lower indices of "dirtiness" for light smokers as compared with other smoking categories, particularly in the 31–50 age window.

TABLE II. Job Title-Based Index of "Dirtiness" of Occupational Profiles by Lifetime Smoking Profile in a Group of 857 Men

		Age window	
		21–30	31–50
Lifetime smoking profile[a]	n	J index[b]	J index
Nonsmoker	100	100 (7.3)	100 (8.2)
Quitter	108	101 (6.5)	99 (7.3)
Light	180	101 (4.9)	97 (5.8)
Heavy	469	98 (3.1)	95 (3.5)

[a]See Table 1 for definitions of four mutually exclusive smoking categories. Note that "quitters" may not yet have quit by age 30.
[b]See Methods section for formula. Each column of indices has been scaled up or down so the nonsmoker value equals 100. Standard error of the index is in parentheses.

TABLE III. Exposure-Based Index of "Dirtiness" of Occupational History by Lifetime Smoking Profile in a Group of 857 Men

		Age window	
		21–30	31–50
Lifetime smoking profile[a]	n	E index[b]	E index
Nonsmoker	100	100 (11.0)	100 (11.1)
Quitter	108	110 (10.8)	95 (9.5)
Light	180	89 (7.6)	76 (6.6)
Heavy	469	99 (5.1)	94 (4.5)

[a]See Table I for definitions of four mutually exclusive smoking categories. Note that "quitters" may not yet have quit by age 30.
[b]See Methods section for formula. Each column of indices has been scaled up or down so the nonsmoker value equals 100. Standard error of the index is in parentheses.

Next we focused on subsets of the sample who had been exposed to various specific occupational exposures. Table IV addresses the relationships between smoking habits and degree of exposure to these substances. For the subgroup of men exposed to each of the ten substances, three indices of exposure are presented: (a) the duration of exposure to the substance of interest, (b) the level of exposure (concentration × frequency) to the substance of interest, and (c) the degree of exposure to all substances as measured by the E index. The table shows no tendency for smokers to allow themselves to be more exposed to the ten selected substances than nonsmokers. Nor were smokers more highly exposed by the global E index. If anything, there was a tendency for nonsmokers and quitters to show higher values of these indices of exposure than current smokers, but this was not consistent across all substances.

Table V summarizes the evidence from Table IV by simply averaging the corresponding indices across the ten substance-defined subgroups. As indicated by the analysis of all 857 subjects (Table III), light smokers had the cleanest job environments.

DISCUSSION

Our study population consisted of French Canadians living in Montreal with less than 11 years' education and born between 1910 and 1930. In the education and years of birth criteria, and in the fact that they are centered in one geographic location, our study population is probably similar to most cohorts that are currently being studied by epidemiologists. There is no obvious reason why smoking-exposure relationships in this population should differ from those in other North American working-class groups of the same birth cohort. However, we cannot generalise our findings to internal comparisons between socially heterogeneous subgroups such as production vs office workers or workers in a plant in the southeast where pollution levels may be high vs workers in a similar plant in the northwest where pollution levels may be low. In such designs the potential for confounding is obvious.

Cohorts are usually defined on the basis of job or industry title. Therefore it would have been interesting for us to establish a number of subgroups of our study population on the basis of job or industry title and study the correlation between smoking and exposure within these subgroups. However, there were not sufficient numbers in specific jobs and industries to make such an approach feasible. All of the approaches involved grouping subjects across occupational and industrial categories. Nevertheless, we believe the various approaches we adopted, and in particular the set of substance-specific analyses, are of relevance to the typical cohort study situation.

The job-title-based approach (J index) included all 857 subjects in this socially homogeneous population. This analysis showed that there was no relation between smoking habits and the amount of time spent in blue or white collar occupations. This would indicate that there was no differential selection by smoking category into clean or dirty job titles and no differential tendency to leave dirty job titles.

The job-title-based index did not take into account the idiosyncracies of each man's situation. Even within a group of men having a given job title there can be considerable variation in the quality and quantity of occupational exposures. The E-index analysis based on all 857 subjects was designed to be sensitive to the specifics of each man's particular job environment. As with the job-title-based index, there were no differences among nonsmokers, quitters, and heavy smokers. However, light

TABLE IV. Mean Duration and Degree of Exposure to Each of Ten Selected Substances Among Men Who Had Been Exposed to Each Substance, by Lifetime Smoking Profile

Subgroups defined by exposure to substance	Lifetime smoking profile[a]	n[b]	Years of exposure to substance[c]	Level of exposure to substance[d]	Exposure-based index combining all substances[e]
Sulphur dioxide	Nonsmoker	15	14.0 (2.7)[f]	100 (40)	100 (18)
	Quitter	16	14.9 (2.5)	114 (26)	94 (13)
	Light	22	11.8 (2.0)	81 (15)	80 (9)
	Heavy	89	13.9 (1.0)	79 (9)	87 (6)
Welding fumes	Nonsmoker	11	16.6 (3.0)	100 (33)	100 (25)
	Quitter	16	15.1 (2.7)	72 (19)	85 (12)
	Light	25	14.1 (2.1)	89 (18)	70 (10)
	Heavy	66	14.2 (1.3)	75 (10)	81 (6)
Engine emissions	Nonsmoker	47	19.3 (1.5)	100 (10)	100 (16)
	Quitter	56	21.2 (1.2)	100 (8)	118 (13)
	Light	83	17.6 (1.1)	92 (6)	68 (7)
	Heavy	243	19.4 (0.6)	104 (4)	86 (6)
Gasoline	Nonsmoker	18	22.1 (2.1)	100 (17)	100 (17)
	Quitter	19	12.9 (2.3)	91 (17)	93 (11)
	Light	22	12.4 (2.1)	89 (17)	87 (14)
	Heavy	67	16.7 (1.2)	87 (9)	94 (8)
Lubricating oil	Nonsmoker	38	20.1 (1.6)	100 (19)	100 (12)
	Quitter	36	16.9 (1.8)	98 (15)	88 (10)
	Light	49	16.3 (1.5)	98 (14)	74 (8)
	Heavy	138	17.0 (0.8)	82 (7)	96 (6)
Solvents	Nonsmoker	36	20.1 (1.6)	100 (12)	100 (11)
	Quitter	44	18.4 (1.6)	105 (13)	91 (10)
	Light	57	18.3 (1.4)	94 (10)	82 (8)
	Heavy	173	18.4 (0.8)	86 (6)	94 (5)
Paints, varnishes, stains	Nonsmoker	20	16.5 (2.1)	100 (23)	100 (13)
	Quitter	24	14.7 (2.0)	139 (27)	107 (16)
	Light	36	13.9 (1.4)	114 (19)	93 (13)
	Heavy	108	15.0 (1.0)	102 (9)	103 (7)
Adhesives	Nonsmoker	10	16.2 (3.6)	100 (24)	100 (22)
	Quitter	16	18.6 (2.5)	89 (21)	88(16)
	Light	21	16.7 (2.2)	106 (26)	104 (14)
	Heavy	72	16.7 (1.2)	135 (15)	103 (7)
Excavation dust	Nonsmoker	7	13.9 (4.6)	100 (38)	100 (21)
	Quitter	10	13.2 (3.5)	152 (38)	54 (12)
	Light	11	14.9 (3.6)	156 (40)	64 (10)
	Heavy	52	12.5 (1.3)	142 (15)	69 (7)
Wood dust	Nonsmoker	18	13.5 (2.2)	100 (19)	100 (19)
	Quitter	23	19.1 (2.2)	99 (16)	135 (18)
	Light	39	14.0 (1.7)	69 (11)	77 (11)
	Heavy	133	15.7 (0.9)	76 (6)	100 (7)

[a]See Table I for definitions of smoking categories.
[b]Number of persons in the smoking category who had definitely been exposed to this substance.
[c]Mean number of years of exposure to this substance during the 21–50 age window among the n persons exposed.
[d]Mean value of concentration × frequency to this substance during the 21–50 age window among the n persons exposed. In each substance-defined subgroup, the values of this index have been scaled up or down so that the value among nonsmokers equals 100.
[e]Mean value of the exposure-based index, E, defined in the Methods section, during the 21–50 age window among the n persons exposed to the index substance. This index includes all substances to which the men were exposed, not just the index substance. In each substance-defined subgroup, the values of this index have been scaled up or down so that the value among nonsmokers equals 100.
[f]Standard error in parentheses.

TABLE V. Mean Durations and Degrees of Exposure to Ten Selected Substances Across the Ten Exposed Subcohorts

Lifetime smoking profile[a]	Means across 10 subgroups[b]		
	Years of exposure to substance	Level of exposure to substance	Exposure-based index combining all substances
Nonsmoker	17.2	100	100
Quitter	16.5	105	95
Light	15.0	98	80
Heavy	16.0	95	91

[a]See Table I for definitions of smoking categories.
[b]Means are computed across the ten subcohorts shown in Table IV. These subcohorts were not mutually exclusive.

smokers had a significantly lower "dirtiness" index than the other groups, particularly in the older age window. On the face of it, Tables II and III seem to indicate not that light smokers avoid or leave job titles which may entail dirty environments but that within a given job title they select the cleaner environments. The explanation for this finding, if it is not a statistical fluke, is not self-evident. That is, if light smokers avoid dirty environments more than heavy smokers, it is difficult to believe that this impulse would not operate at least as strongly among nonsmokers. If true, it underlines the fact that cigarette smoking is a complex psychosociological phenomenon.

In case the strategy of summing indices over all men and all exposures was too crude or constitutes comparing "apples with oranges" we also carried out a number of substance-specific analyses. Each of these was based only on the subset of men who had ever definitely been exposed to the substance and thus had the career opportunity to be exposed to it for longer or shorter periods and at higher or lower levels. These analyses come closest to simulating the typical uni-occupation or uni-industry situation. Because these analyses were based on fewer subjects, the results were subject to greater statistical variation. Overall, there were no systematic differences among smoking categories, though again the tendency was for light smokers to evidence less exposure, by the various indices examined.

Because disease risk in relation to smoking generally exhibits dose-response relationship with highest risk for heavy smokers and lowest risk for nonsmokers, the dangers of biased subgroup comparisons would be greatest if there were a graded relationship between the four smoking categories and dirtiness of the job history. This clearly was not the case. While the difference between light smokers and the other categories was discernible, the net biasing effect of this difference on estimates of risk in cohort studies would probably be very small, if not negligible. This curious phenomenon should nevertheless be further investigated and its potential impact assessed more carefully.

It has been hypothesized that nonsmokers would be less tolerant of polluted environments than smokers and select themselves out. This would have led to lower "dirtiness" indices among nonsmokers than smokers. However, two other mechanisms are equally plausible which would have the opposite effect. First, it is conceivable that the incremental pollution from occupational sources is more irritating to a smoker than to a nonsmoker. (This is a version of "the straw that broke the camel's back.") A second is a version of the healthy worker effect. If nonsmokers remain

more robust and physically fit than do smokers, then they may be able to better maintain themselves in physically demanding jobs. Often, the more physically demanding jobs are those with greater opportunity of exposure to dusts, fumes, and pollution in general. The fact that we observed little real difference in "dirtiness" indices between smokers as a whole and nonsmokers may mean that influences were operating in both directions and cancelled each other out, or that none of them is important. In fact, the "dirtiness" indices tended to be slightly higher among nonsmokers, and thus the tendency for nonsmokers to prefer clean environments may be weaker than the countervailing tendencies.

The main limitation to these findings concerns the measures of level of exposure. The various indices, based on retrospective exposure assessment and on arbitrary functional forms, may be crude approximations of the truth. However, we believe these measures are correlated, albeit imperfectly, with the truth, and in the absence of more valid information, provide a useful means of studying the problem. If the relationship between smoking and exposure levels were subtle, it would not likely be detected by our study. But if the relationship were subtle, it would not pose a serious threat of confounding.

This is the only study we know of that addresses the correlation between smoking and exposure level within the kinds of socially homogeneous populations that are typical of cohort studies. The generalizability of a single set of findings is always questionable. It is therefore important to multiply the evidence on this issue. We believe there are many investigators who have information on smoking habits and exposure of members of particular cohorts. We encourage them to investigate and report the correlations.

In conclusion, in a socially, culturally, and demographically homogeneous sample of men there was no monotonic association between level of smoking, a correlate of disease risk, and level of occupational exposure. This lack of association held true whether the level of occupational exposure was assessed via an overall impression of the job titles held or by a weighted count of all occupational exposures attributed to the workers by a trained team of chemists and hygienists. In case the approach of examining these associations among all workers was too broad we also sought such associations within subsets of the sample defined by exposure to a given substance. Within such groups, there was no consistent association between smoking profile and level of exposure to corresponding substances.

Smoking is a potential confounding factor in occupational cohort studies for disease outcomes which are associated with smoking. If the smoking habits of members of a cohort are unknown or if they are known to differ from those of the standard reference population, and if any information is available which would permit distinguishing workers with different degrees of exposure to an agent(s) of interest, then a so-called internal comparison is an attractive analytic strategy. Our results indicate that internal comparisons are unlikely to be seriously confounded by differences in smoking habits.

ACKNOWLEDGMENTS

This work was funded by grants from the Institut de recherche en santé et securité au travail du Québec, National Health Research and Development Programme, and the National Cancer Institute of Canada. Jean Pellerin helped with data

management. Lorne Wald and Jean Pellerin carried out computer programming. Marc Brunet analysed a preliminary data set. Howard Kemper, Louise Nadon, and Ramzan Lakhani carried out some of the chemical coding. Linda Carfagnini prepared the manuscript.

REFERENCES

Asp A (1984): Confounding by variable smoking habits in different occupational groups. Scand J Work Environ Health 10:325–326.

Blair A, Hoar S, Walrath J (1985): Comparison of crude and smoking-adjusted standardised mortality ratios. J Occup Med 27:881–884.

Brackbill R, Frazier T, Shilling S (1988): Smoking characteristics of U.S. workers, 1978–1980. Am J Ind Med 13:5–41.

Gérin M, Siemiatycki J, Kemper H, Bégin D (1985): Obtaining occupational exposure histories in epidemiologic case-control studies. J Occup Med 27(6):420–426.

Siemiatycki J, Day N, Fabry J, Cooper J (1981): Discovering carcinogens in the occupational environment: A novel epidemiologic approach. JNCI 66:217–225.

Siemiatycki J, Richardson L, Gérin M, Goldberg M, Dewar R, Désy M, Campbell S, Wacholder S (1986): Associations between several sites of cancer and nine organic dusts: Results from an hypothesis-generating case-control study in Montreal, 1979–83. Am J Epidemiol 123(2):235–249.

Steenland K, Beaumont J, Halperin W (1984): Methods of control for smoking in occupational cohort mortality studies. Scand J Work Environ Health 10:143–149.

Stellman SD, Boffetta P, Garfinkel L (1988): Smoking habits of 800,000 American men and women in relation to their occupations. Am J Ind Med 13:43–58.

Sterling TD, Weinkam JJ (1978): Smoking patterns by occupation, industry, sex and race. Arch Environ Health 33(6):313–317.